

1. 250 mL of a weak acid are titrated with 0.175 M NaOH. The equivalence point occurs after adding 136 mL NaOH. The pH at the half-equivalence point is 5.25.

- a. What was the initial concentration of the weak acid?

$$.136 \text{ L} \times \frac{0.175 \text{ mol}}{1 \text{ L}} = 0.0238 \text{ mol OH}^- = 0.0238 \text{ mol HA}$$

$$\frac{0.0238 \text{ mol HA}}{0.250 \text{ L}} = \underline{\underline{0.0952 \text{ M HA}}}$$

- b. What is the pH at the equivalence point?

$$[\text{A}^-] = \frac{0.0952 \text{ mol A}^-}{.250 \text{ L} + .136 \text{ L}} = 0.2466 \text{ M}$$

$$\text{p}K_a = 5.25; K_a = 5.623 \times 10^{-6}; K_b = 1.778 \times 10^{-9}$$

$$K_b = 1.778 \times 10^{-9} \cong \frac{x^2}{.2466}; \quad x = [\text{OH}^-] = 2.094 \times 10^{-5}; \quad \text{pH} = 14 - 4.679 = \underline{\underline{9.32}}$$

- c. What is the pH after adding 50, 75, and 150 mL NaOH?

$.05 \text{ L} \times \frac{0.175 \text{ mol}}{1 \text{ L}} = 0.00875 \text{ mol OH}^-$ $\text{HA} + \text{OH}^- \rightarrow \text{A}^- + \text{H}_2\text{O}$ St .0238 mol A 0.00875 mol N .01505 mol 0 mol 0.00875 mol $\text{pH} = 5.25 + \log \frac{0.00875}{0.01505} = \underline{\underline{5.01}}$	$.075 \text{ L} \times \frac{0.175 \text{ mol}}{1 \text{ L}} = 0.013125 \text{ mol OH}^-$ $\text{pH} = 5.25 + \log \frac{0.013125}{0.010675} = \underline{\underline{5.34}}$
	$.150 \text{ L} \times \frac{0.175 \text{ mol}}{1 \text{ L}} = 0.02625 \text{ mol OH}^-$ 0.00245 mol excess OH⁻ remain. $[\text{OH}^-] = \frac{0.00245 \text{ mol}}{.250 \text{ L} + .150 \text{ L}} = 0.006125 \text{ M}$ $\text{pH} = 14 - 2.21 = \underline{\underline{11.79}}$

2. 300 mL of 0.155 M acetic acid, HC₂H₃O₂, are titrated with 0.225 M NaOH.

- a. What volume of NaOH is required to reach the equivalence point?

$$0.0465 \text{ mol} = 0.207 \text{ L}$$

- b. What is the pH at the half-equivalence point and equivalence point?

$$\text{Acetic acid } K_a = 1.8 \times 10^{-5}, \text{ p}K_a = \underline{\underline{4.74}} = \text{pH at half-equivalence point.}$$

$$[\text{Ac}^-] = \frac{0.0465 \text{ mol}}{.3 \text{ L} + .207 \text{ L}} = 0.0917 \text{ M Ac}^- \text{ at equivalence point.}$$

$$K_b = 5.56 \times 10^{-10} \cong \frac{x^2}{0.0917}$$

$$[\text{OH}^-] = 7.14 \times 10^{-6}; \text{ pH} = \underline{\underline{8.85}} \text{ at equivalence point}$$

- c. What is the pH after adding 80, 120, and 300 mL NaOH?

$$4.54, 4.88, 12.54 \text{ (excess OH}^-)$$

3. 100 mL of 0.755 M HCl is titrated with 0.525 M NaOH.

a. What volume of NaOH is required to reach the equivalence point?

$$0.0755 \text{ mol H}_3\text{O}^+ \text{ initially} = 0.0755 \text{ mol OH}^- \text{ added} = \underline{0.144 \text{ L}}$$

b. What is the pH at the half-equivalence point (hint, you cannot use the H-H equation) and equivalence point?

$$0.0755 \text{ mol} / 2 = 0.03775 \text{ mol OH}^- \text{ added} = \text{mol H}_3\text{O}^+ \text{ remaining}$$

$$[\text{H}_3\text{O}^+] = \frac{0.03775 \text{ mol}}{.1 \text{ L} + \left(\frac{.144 \text{ L}}{2}\right)} = 0.220 \text{ M}; \text{pH} = \underline{0.658}$$

c. What is the pH after adding 25, 50, 100, and 200 mL of NaOH?

$$0.30, 0.48, 0.94, 12.99 \text{ (excess OH}^-)$$

4. 225 mL of 0.435 M $\text{NH}_3(aq)$ are titrated with 0.150 M HCl.

a. What volume of HCl is required to reach the equivalence point?

$$0.0979 \text{ mol NH}_3 \text{ initially} = 0.0979 \text{ mol H}_3\text{O}^+ \text{ added} = \underline{0.653 \text{ L}}$$

b. What is the pH at the half-equivalence point and equivalence point?

$$\text{NH}_3 K_b = 1.76 \times 10^{-5}; \text{NH}_4^+ K_a = \frac{1 \times 10^{-14}}{1.76 \times 10^{-5}} = 5.68 \times 10^{-10}; pK_a = \underline{9.25} = \text{pH at half-eq point}$$

$$[\text{NH}_4^+]_{\text{eq}} = \frac{0.0979 \text{ mol}}{0.225 + 0.0653 \text{ L}} = 0.111 \text{ M}$$

$$K_a = 5.68 \times 10^{-10} \cong \frac{x^2}{0.111}$$

$$[\text{H}_3\text{O}^+] = 7.96 \times 10^{-6} \text{ M}; \text{pH} = \underline{5.10} \text{ at equivalence point}$$

c. What is the pH after adding 300, 400, and 700 mL HCl?

$$9.32, 9.05, 2.11 \text{ (excess H}_3\text{O}^+)$$